Appendix C

Supplemental Benefits Calculations

APPENDIX C

EPA developed a three-step method for extrapolating the results of the Santa Monica Bay epidemiological study (Haile et al., 1996) to estimate the potential health impacts to swimmers in marine waters of the Phase II Storm Water Rule:

- estimate potential range of contamination concentrations at storm sewer drains in Phase II coastal communities
- estimate potential number of swimmers who swim near storm sewer drains in Phase II coastal communities
- estimate incremental illnesses using “attributable numbers” from the Santa Monica Bay study (Haile, et al., 1996).

Assuming that swimmers are not likely to swim near storm sewer drains during “wet weather” flows, the estimated number of incremental illnesses represents illnesses that occur during “dry weather” when low flows in storm sewers are caused by illicit connections and infiltration. By targeting the removal of such flows, the Phase II Storm Water rule should reduce the number of related illnesses among swimmers in marine waters.

Potential Range of Contamination Concentrations

The attributable numbers in the Santa Monica Bay study (Haile et al., 1996) depend on total coliform (TC) concentrations in marine waters near storm sewer drains. The concentration of total coliform (TC) in the vicinity of a storm sewer drain depends on the extent to which the waste water mixes with the receiving water body. The extent of mixing is site specific and depends on several parameters such as the location of the outfall, the type of outfall, and currents in the receiving water. All of these parameters can be grouped into one variable, the dilution ratio. The dilution ratio can be used as a measure of the level of mixing at the discharge point or at the vicinity of an ocean outfall.

Dilution ratios at coastal sewer drains vary greatly and are specific to each system. EPA does not have location information for the drains in coastal Phase II communities, much less location-specific dilution ratios. For a general analysis, EPA assumed that the dilution ratio varies from 100 to 1,000. This range of dilution ratios is representative of mixing conditions encountered at the vicinity of coastal sewer drains. A dilution ratio of 100 represents a low mixing level at the ocean outfall and is used to represent the high-end of expected TC concentrations. Similarly, the dilution ratio of 1,000 indicates a high level of mixing and is used to represent the low-end of TC concentrations. The die-off and transport of TC organisms is not incorporated in the estimation since the intent is to estimate the TC concentrations in the immediate vicinity of the discharge point. Such die-off and transport components are usually incorporated when estimating the TC concentration at various distances from the outfall.

Combining these dilution ratios with an estimate of mean TC concentration in waste water, EPA obtained a range of TC concentrations at coastal sewer drains. EPA (1976) reports a mean TC concentration of 3.10^5/100 ml for the discharge from storm sewers and unsewered areas. The resulting concentration range at the outfall is 300 cfu/100 ml to 3000 cfu/100 ml. The low and high ends of this range fall on either side of the 1,000 cfu/100 ml cut point for the attributable numbers in the Santa Monica Bay study. This allowed EPA to use the low attributable numbers to characterize low health impacts and the high attributable numbers to characterize high health impacts.

Potential Number of Swimmers at Ocean Sewer Drains

In the second step in the analysis, EPA estimated the annual number of people who might be exposed to these concentrations as a result of swimming near these drains. The Section 6.2.2 on the benefits of enhanced marine recreational swimming estimated that approximately 166 million swimming days take place annually at Phase II beaches. Some fraction of these swimming trips will bring people within one yard of a storm sewer drain, which is the impact range for the attributable numbers this analysis used from the Santa Monica Bay study. EPA used the exposure rates from the Santa Monica Bay study to establish an upper bound of 7% (i.e., of the 11,686 people in the final sample, 827 swam within one yard of one of the three drains in the study areas). The resulting upper bound exposure estimate is 11.6 million swimmers per year. It is interesting to note that children appeared more likely than adults to swim near these drains; children made up 48% of the study sample, but they accounted for 62% of the subsample that swam within one yard of an outfall.

The 7% upper bound most likely overstates the percentage of people who swam within one yard of an outfall because it is based on the swimmers in the three study areas of the bay. EPA has no estimate of total swimming at the beaches, however, to adjust the figure. Furthermore, it is unknown how representative this percentage is of distribution of swimmers at Phase II beaches.

Incremental Number of Illnesses

A study of 13,278 swimmers at three public beaches in Santa Monica Bay found that people who swam within 100 yards of storm drains experienced increased incidences of gastrointestinal and respiratory diseases, and that illness rates were often highest among those who swam in the immediate vicinity of the storm drain (Haile et al., 1996). The increased incidence of illness was associated with swimming in areas where monitoring results showed high densities of bacterial indicators. The study identified illicit connections to storm sewer drains as possible sources of contamination.

The Santa Monica Bay study did not calculate specific dose-response curves for infection and symptomatic illness as a function of concentrations of the indicator microorganisms such as TC or fecal coliforms (FC) that were detected in recreational waters because of the extensive variability in exposures and observed symptoms in bathers who were interviewed. Instead, the study presented incidence rates for symptoms that could be attributed to exposures to wastewater from three beach storm sewer drains under various conditions.

The study calculated these incidence rates, termed "attributable numbers," as the difference between the number of symptomatic cases resulting from exposure at the drains and the number of cases at the control distance of 400 yards down current from the drains. The study reported attributable numbers, which were normalized to expected numbers of illnesses per 10,000 exposures, for several exposure levels that were separated by observed TC concentration "cut points," including the following:

- total exposures at all TC concentrations;
- exposures when TC concentration was > 1,000 colony-forming units (cfu) /100 ml; and
- exposures when the TC concentration was > 5,000 cfu /100 ml.

The attributable numbers depended on the TC concentration and on the TC to fecal coliform (FC) ratio. Lower TC:FC ratios were assumed to represent higher relative rates of fecal contamination of the wastewater. Exposures at TC concentrations > 1,000 cfu/100 ml and with TC:FC ratios of five or less appeared to be more significant in causing disease symptoms than other exposures. The study presents attributable numbers for each type of health effect by TC:FC ratio. Exhibit C–1 summarizes low and high attributable numbers for five different TC:FC ratios. The low values shown in the exhibit correspond to attributable numbers for exposures when TC concentration is < 1,000 cfu/100 ml and the high values correspond to exposures when TC is > 1,000 cfu/100 ml. EPA used the low and high attributable numbers to reflect uncertainty about whether TC concentration rates from illicit sewer connections are likely to be above or below the 1,000 cfu/100 ml cut point. EPA averaged the attributable numbers across the TC:FC ratios reported in the exhibit to incorporate additional uncertainty about the level of contamination at storm sewer drains.

Exhibit C–1. Summary of Attributable Numbers by Reported Health Symptom, Total Coliform to Fecal Coliform Ratio, and Total Coliform Concentration (additional cases above background levels per 10,000 people exposed)

Symptom	TC/FC = 2		TC/FC = 4		TC/FC = 5		TC/FC = 6		TC/FC = 8		Average[1]	
	Low[2]	High[2]	Low	High	Low	High	Low	High	Low	High	Low	High
Fever	—	194	—	139	—	128	—	86	—	89	—	127
Chills	—	0	—	99	—	87	—	68	—	43	—	74
Nausea	—	65	—	180	—	152	—	151	—	137	—	137
Vomiting	—	140	—	90	—	71	—	68	—	38	—	81
Diarrhea	19	222	105	187	106	180	167	167	116	189	103	189
Cough	70	236	56	132	59	125	58	95	51	132	59	144
Cough+phlegm	—	165	—	40	—	36	—	34	—	24	—	60
Runny nose	—	492	—	141	—	163	—	105	—	170	—	214
Sore throat	63	247	67	121	77	93	73	104	58	128	68	139
HCGI 1[3]	—	167	—	96	—	83	—	55	—	42	—	89
HCGI 2[4]	0	117	28	110	28	104	19	99	48	79	31	102
SRD[5]	—	220	—	84	—	69	—	68	—	71	—	102

Notes:

[1] Simple average across five TC/FC ratios, except the high estimate for chills, which is an average over four ratios excluding a missing ratio for the TC/FC=2
case, and the low estimate for HCGI 2, which is an average over four rations excluding a missing ratio for the TC/FC=2 case.

[2] Low values correspond to TC concentrations of <1000 cfu/100 ml and high values correspond to TC concentrations of >1000 cfu/100 ml.

[3] Highly credible gastroenteritis one (HCGI 1) is defined as a person having either 1) vomiting, 2) diarrhea and fever, or 3) stomach pain and fever.

[4] Highly credible gastroenteritis two (HCGI 2) is defined as a person having vomiting and fever.

[5] Significant respiratory disease (SRD) is defined as a person having 1) fever and nasal congestion or 2) fever and sore throat and 3) cough with sputum.

Source: Haile et al. (1996)

Using the exposure assumption described above, EPA multiplied the number of annual exposures (divided by 10,000 to match the attributable number units, which are cases per 10,000 people) by the average low and high attributable numbers for each health symptom. For example, given the average high attributable number for nausea of 137 and the exposure estimate of 11.6 million, the health impact calculation is:

$$137 \times (11{,}640{,}000 / 10{,}000) - 159{,}500 \text{ additional cases of fever.}$$

Exhibit C–2 summarizes the potential increase in the number of illness symptoms for the exposure assumption and the high and low concentration assumptions (i.e., > 1000 cfu/100 ml and < 100 cfu/100 ml). This analytical method produces a wide range of potential cases for each symptom because the attributable numbers are based on a cut point rather than a smooth exposure function.

Exhibit C–2. Estimated Marine Health Impacts Associated with Contaminated Dry Weather Discharges from Storm Sewers in Phase II Coastal Communities by Symptom, Exposure Assumption, and Total Coliform Concentration

Symptom	Low Contamination (TC <1000 cfu/100 ml)	High Contamination (TC >1000 cfu/100 ml)
Fever	0	148,068
Chills	0	86,431
Nausea	0	159,475
Vomiting	0	94,754
Diarrhea	119,432	220,006
Cough	68,446	167,624
Cough+phlegm	0	69,610
Runny nose	0	249,340
Sore throat	78,690	161,338
HCGI 1[1]	0	103,135
HCGI 2[2]	35,795	118,501
SRD[3]	0	119,199

Notes:
[1] Highly credible gastroenteritis one (HCGI 1) is defined as a person having either 1) vomiting, 2) diarrhea and fever, or 3) stomach pain and fever.
[2] Highly credible gastroenteritis two (HCGI 2) is defined as a person having vomiting and fever.
[3] Significant respiratory disease (SRD) is defined as a person having 1) fever and nasal congestion or 2) fever and sore throat and 3) cough with sputum.

Because the health risk estimates were based on contamination cut points rather than a dose-response function, EPA could only estimate changes in health risks in instances where the rule is expected to completely remove a contamination source. Thus, the analysis is restricted to evaluating avoided health impacts caused by illicit connections and infiltration that generate contaminated sewer discharges during dry weather periods because the rule is expected to remove these contamination sources. As the Haile et al. (1996) study shows, contaminated flows during dry weather can lead to additional health risks, e.g., storm sewers discharge an average of 10–25 million gallons per day into Santa Monica Bay during the dry summer months, which is when the study was conducted.

Consequently, the health risk analysis was not able to assess avoided health impacts during wet weather events because some contaminated sewer flow will reach marine environments. The rule is expected to reduce the contamination levels in wet weather discharges from storm sewers in Phase II communities, but EPA is not able to estimate changes in health impacts because the method used can only distinguish between contamination levels above and below the 1000 cfu/100 ml cut point; i.e., changes in contamination levels above or below the cut point will not generate changes in symptoms using this approach. Consequently, if people are exposed to contaminants in wet weather discharges at Phase II beaches (i.e., if beaches are not closed to avoid potential health impacts), then there may be some additional health benefits associated with reducing pathogen contamination levels in wet weather flows that are not captured by the analysis.

The analysis also implicitly assumes that there are no instances when a person is swimming next to a storm sewer drain and there is no contaminated water coming from the drain. In the larger Phase II coastal communities, there may be a persistent flow from these drains even in dry weather. In smaller Phase II communities, however, there may be periods when there is no contaminated flow coming from the drain. Any adjustment to account for this situation would be necessarily arbitrary and should be conducted only for a sensitivity analysis. The one and a half order of magnitude range of the current exposure assumption is wide enough to potentially account for this additional source of uncertainty.